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ENSO Simulation in CGCMs and the Associated Errors in Atmospheric Response.

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Introduction

Tropical Pacific variability, and specifically the simulation of ENSO in coupled ocean-atmosphere general circulation models (CGCMs) has previously been assessed in many studies (McCreary and Anderson [1991], Neelin et al. [1992], Mechoso et al. [1995], Latif et al. [2000], and Davey et al. [2000]). These studies have concentrated on SST variations in the tropical Pacific, and discussions of the atmospheric response have been limited to east- west movements of the convergence zone. In this paper we discuss the large-scale atmospheric response to simulated ENSO events. Control simulations from 17 global CGCMs from CMIP (Meehl et al. [2000]) are studied. The web site http://www-pcmdi.llnl.gov/cmip/modeldoc provides documentation of the configurations of the models.

Results

For each model we have calculated the Southern Oscillation Index (SOI) and surface air temperature anomalies (TASA) in the NIÑO3 region (5˚ N-5˚ S, 150˚ W-90˚ W); the area of the Pacific where the most dramatic changes in temperature associated with ENSO events are found. Warm (cold) events are defined when the standardized DJF seasonal anomalies of the NIÑO3 TASA is ≥ 0.6 (≤ -0.6) and the standardized SOI is ≤ -0.6 (≥ 0.6). The year preceding the anomalous DJF season is denoted "year 0", consistent with the definition of Rasmusson and Carpenter [1982]. The time evolution of monthly NIÑO3 TASA composites are plotted for warm events in Fig. 1, where we have used the GISST 2.2 data and the CRU SOI to form the observed composites. The shaded area denotes the one standard deviation envelope of the observed NIÑO3 SSTA evolution from the GISST 2.2 dataset. The phase locking of the warm and cold events with the seasonal cycle is readily seen in the observations, with the peak of the events occurring in the winter of year(+1). This similarity in phasing of individual events, as described in Rasmusson and Carpenter [1982], shows that while the amplitudes of El Niño episodes vary, their phasing can be remarkably similar in that the peak SST anomalies occur in the boreal winter. Many of the models do not show pronounced phase locking in the temperature evolution, and they tend to lie outside the envelope of observed events in the boreal winter of year(+1). These models also do not simulate well the transition from negative to positive anomalies seen in the observations. The models that compare well with the observations are BMRC, CCSR, ECHAM4/OPYC3, HadCM2 (flux-corrected models), and CERFACS, DOE- PCM, and HadCM3 (non-flux-corrected models).

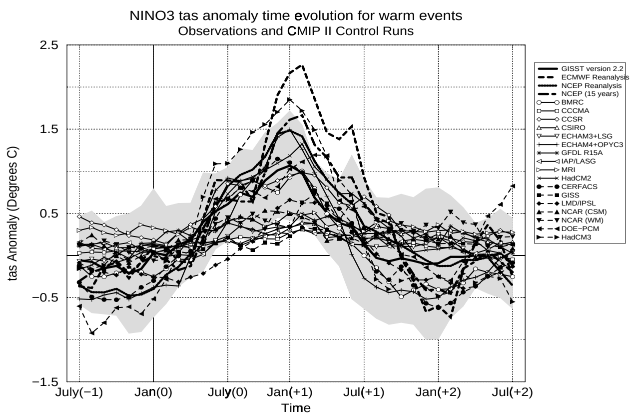

Figure 1.

To examine the global atmospheric response at the peak of ENSO the DJF seasonal anomalies of the TAS, mean sea-level pressure (PSL) and precipitation (PR) were composited based on the events used to generate the composites in Fig. 1. For El Nino, composite anomalies of TAS and PSL from the NCEP reanalysis (1949-1998) are shown in Fig. 2. Fig. 2 shows the dramatic perturbation to the Walker circulation and the warm TAS anomalies in the tropical Pacific. Enhanced rainfall overlies the warm temperature anomalies in the tropical Pacific, and there is evidence of an eastward displacement of the South Pacific Convergence Zone (not shown). In the Pacific Ocean, the dateline is a key region for the anomalies of TAS and PSL. Specifically, this is the location of transition for Walker circulation anomalies and to the east of the dateline the largest positive TAS anomalies are found. With these robust features of ENSO in mind, we find that the simulated warm event composites can be categorized into four groups.

(a) **(b)**

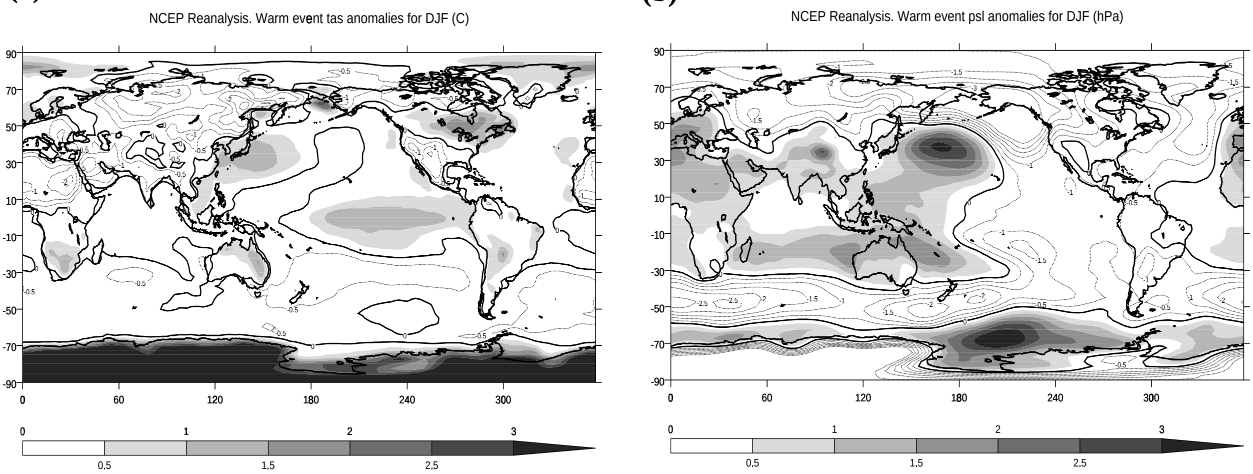

Figure 2. NCEP Reanalysis. DJF composites for warm events. (a) TAS, (b) PSL (Positive anomalies shaded, negative anomalies contoured)

Group 1: CERFACS, ECHAM4/OPYC3, HadCM2, and HadCM3 are most consistent with observations. A representative model (ECHAM4/OPYC3) is shown in Fig. 3. Notably, they have well defined Walker circulation anomalies, with enhanced TAS anomalies extending from the tropical central Pacific to the west coast of South America. These models also simulate well the associated El Niño rainfall in the tropical Pacific.

(a) **(b)**

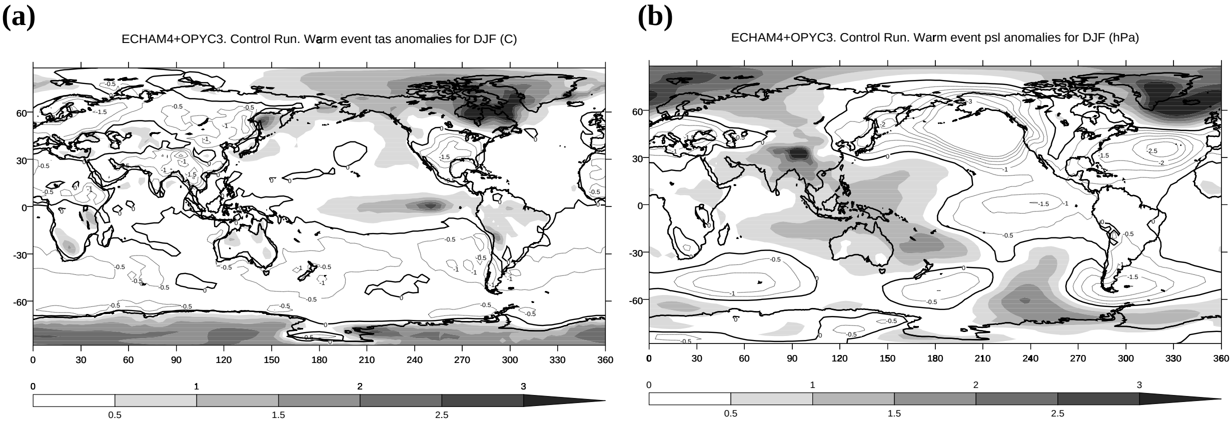

Figure 3. ECHAM4/OPYC3 control run. DJF composites for warm events. (a) TAS, (b) PSL

Group 2: BMRC, CCSR, and CSIRO are characterized by a westward displacement of the Walker circulation anomalies (BMRC shown in Fig. 4). In these models, positive PSL anomalies >0.5hPa extend to only ~150˚E in the tropical Pacific. The maximum TAS warming is located in the tropical central Pacific Ocean, while the anomalies closer to South America are decidedly weaker than observed. Enhanced rainfall of >0.5mm day^{-1} fails to extend east of ~150˚W in the equatorial Pacific, consistent with the westward displacement of temperature and pressure anomalies.

(a) **(b)**

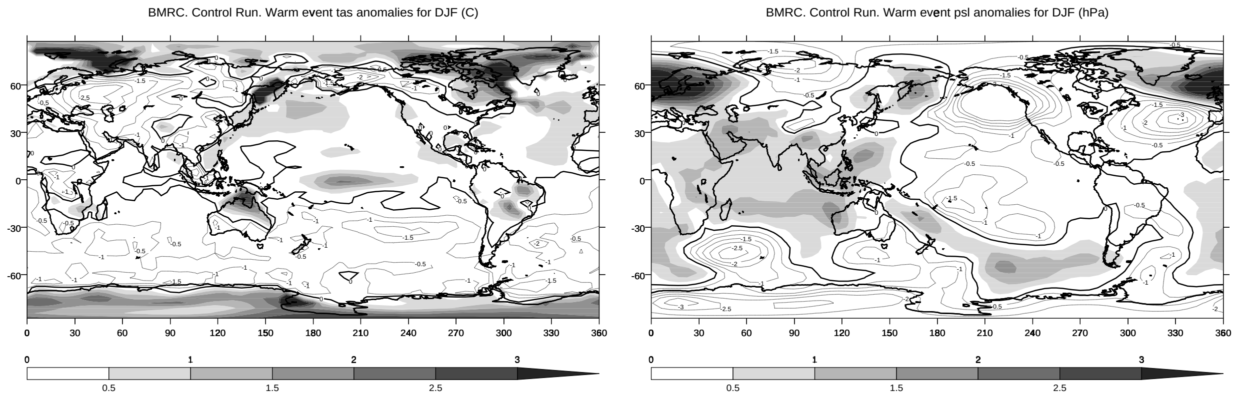

Figure 4. BMRC control run. DJF composites for warm events. (a) TAS, (b) PSL

Group 3: CCMA, ECHAM3/LSG, GFDL, IAP/LASG, MRI, and NCAR/WM exhibit a more pronounced westward displacement of the Walker circulation and/or very weak positive PSL anomalies in the vicinity of the Maritime continent (CCCMA, Fig. 5). The TAS anomalies in the tropical Pacific are very weak. Other than GFDL, all of these models have a warm Northern Hemisphere over the Pacific Ocean, failing to simulate the reduced TAS that extends from the Maritime continent into the northeastern extratropical Pacific Ocean. only CCMA and GFDL have their strongest positive rainfall anomalies near the dateline. The remaining models unrealistically have their enhanced rainfall anomalies in the vicinity of the Maritime continent.

(a) **(b)**

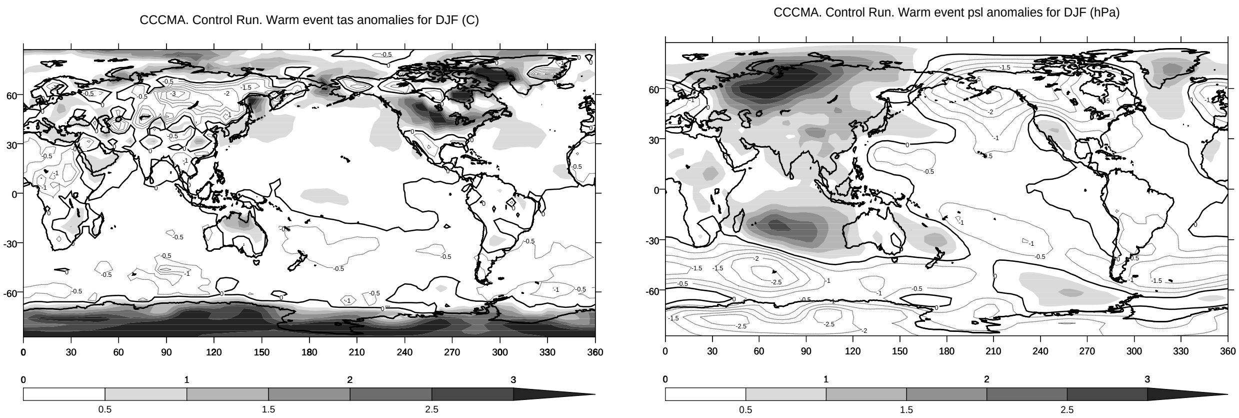

Figure 5. CCCMA control run. DJF composites for warm events. (a) TAS, (b) PSL

Group 4: The remaining models, DOE-PCM (shown in Fig. 6), GISS, LMD/IPSL, and NCAR/CSM, are characterized by hemispheric PSL anomalies in the Pacific that are more consistent with a modification of the Hadley circulation rather than the Walker circulation. North of the equator the tendency is for negative PSL anomalies, while south of the equator the PSL anomalies are positive. Consistent with these errors in the circulation and temperature, the rainfall anomalies clearly reflect a northward displacement of the tropical convergence zone.

(a) **(b)**

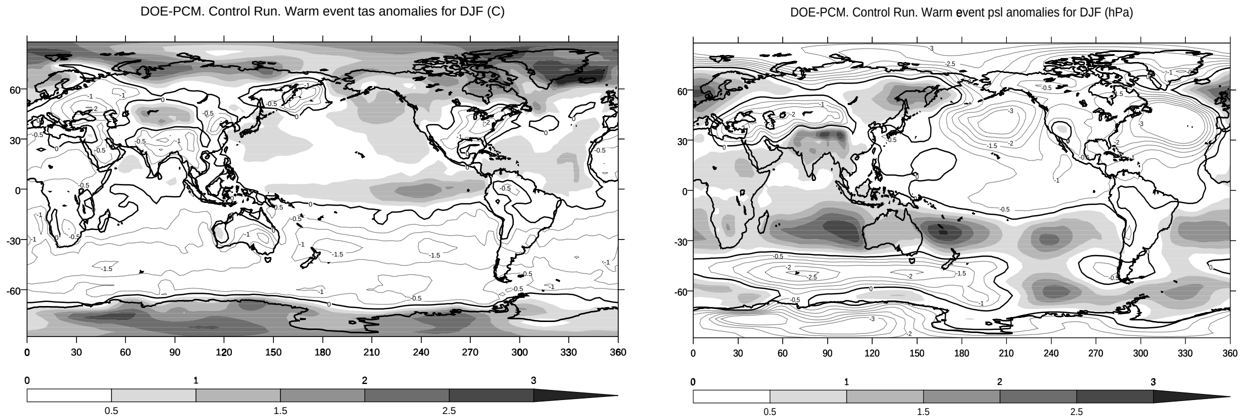

Figure 6. DOE-PCM control run. DJF composites for warm events. (a) TAS, (b) PSL

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